Space Weather Technical Forecast

Issued on Wednesday, 28 December 2022 at 01:08 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Risk of Minor Geomagnetic Storms throughout, peak Chance Friday 30 December. Chance of M-class flares throughout. Likely initial Active electron fluence reducing through the UTC working week.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Moderate through the UTC day of Tuesday 27 December, with X-ray flares recorded at GOES16 showing an uptick in magnitude relative to the Christmas period, with occasional M-class activity developing. These flares included an M2.0 flare at 27/0054UTC and M1.0 flare at 27/0814UTC, both likely from AR3176, as well as an M1.2 from AR3169 at 27/1626UTC.

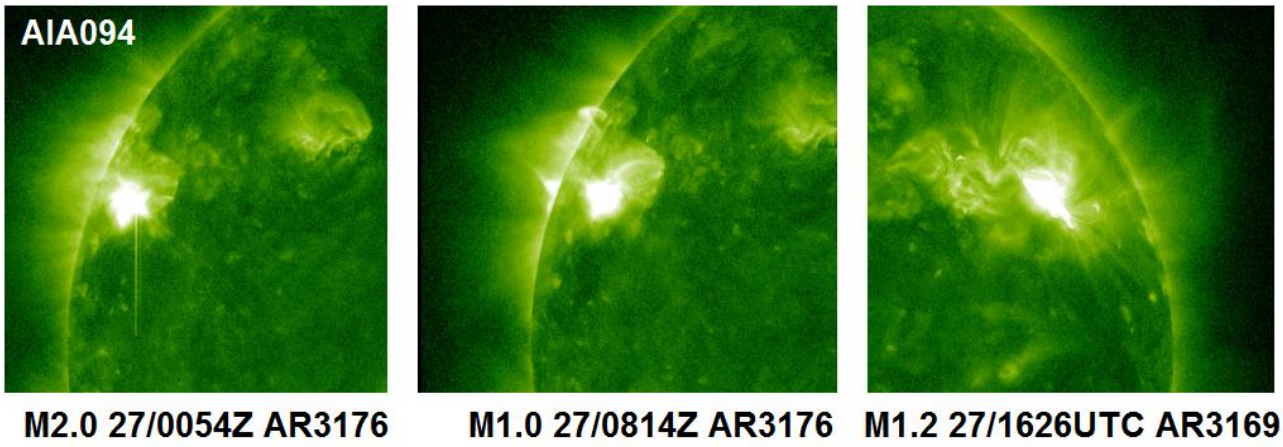

Figure 0: AIA094 imagery of the three M-class flares observed in the 24 hours.

The above sunspot regions were two of five that have been numbered on the facing side, although there are tentative signs of a new arrival on the southeast limb, with exact detail here to be determined. The most dynamic region on the disc was the most active, AR3176 in the northeast, which saw areal growth, spreading and development of intermediate spots in the period to finish the 24 hours as a Dai/Beta. AR3169 remains the largest group, with a spreading trend that saw its span surpass 20 degrees solar longitude, although there were some signs of decay in its intermediate portion. The remaining groups on the disc were all smaller and magnetically simpler, with slow decaying or stable trends.

Regarding potential sources of Coronal Mass Ejections (CMEs) in the period, most observed minor dimming activity was based on either limb, with a late prominence eruption (27/2100UTC) from the southeast near the assumed location of an arriving spot group, and a later one in the west at 27/2200UTC. No Earth-directed CMEs were detected in available imagery.

Solar Wind / Geomagnetic Activity: Solar wind speeds, as measured by DSCOVR and ACE at L1 were suggestive of possible CME influence overlying a positive fast wind. The assumed

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sources are the tail end of the 24/0230UTC northeast quadrant CME, with possible contribution later in the period from the 24/0800UTC CME, although the latter is more conjectural. The fast wind is most likely from CH57/+. Measurement of the solar wind parameters remains relatively noisy, with less precision possible than would normally be the case.

The solar wind speed has been Elevated in the low-500s of km/s in the past 24 hours on a relatively flat trend. The solar wind density was especially erratic, owing to differences in character between measuring satellites, however appears to have remained largely on a stable tendency below 10ppcc throughout. The IMF showed a smooth sinusoidal trend, peaking at 9nT during the UTC morning of 27 December before tailing off as the period drew to a close. The north-south component, Bz, was also smooth, but almost entirely anti-aligned with Earth's field until 27/1630UTC. Upon resumption of a more variable character, geomagnetic indices peaked, with a 62.0nT deflection in Hartland BGS Magnetometer at 27/1618UTC. There was a corresponding slight blip on the ACE EPAM LEMS trace at this time, but on the whole low energy protons were on a downward trend after the posited 24/0230UTC CME's arrival the day before. It is not impossible that there was some additional input from the awaited 24/0800UTC CME, but this is perhaps an outside chance given the lack of other measurement discontinuities at L1 satellites. Finally, the phi angle was mostly positive (away from the Sun) but displaying a more neutral tendency for a time between 27/0600 and 27/1200UTC.

The net effect of the above solar wind measures was for provisional Minor Geomagnetic Storm G1 intervals, realised as a Kp '5-' in the 15-18UTC interval, and revised upwards after-the-fact to '5-' again for the 03-06 and 06-09UTC intervals.

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10MeV) as measured at GOES16 remained at Background levels.

High energy electron flux as recorded at GOES16 (greater than 2MeV), showed a rising trend as geomagnetic activity lessened into the UTC evening, with Normal Background flux eventually rising to a peak of High and 1630pfu at 27/1715UTC before waning. 24-hour integrated electron fluence followed a declining then recovering trend, recording 3.47e7 integrated pfu at 28/0001UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity carries a daily Chance of M-class activity, with the main contributions from AR3169, AR3176 and perhaps now also an arriving southeastern limb spot group. AR3169 is expected to depart the Earth-facing side through the course of day three, Friday 30 December, with the chances of R1 correspondingly falling slightly given the uncertain contribution from any eastern limb arrivals at present.

Solar Wind / Geomagnetic Activity: There are up to two fast wind enhancements due in the period, firstly the incipient CH57/+, with CH59/+ then due before the UTC weekend. Overlying this is a possible glance from a CME that left the Sun on 25 December, which should pass 1AU on 29 December, albeit with low confidence. A CME from 24/0800UTC was due on 27 December. There are three possibilities as regards this feature: firstly it has now already passed nearby to little effect; secondly it contributed to geomagnetic activity on 27 December; else thirdly it remains outstanding but should have its impacts reduced for being late in arriving (i.e. slower and less impactful). No new CMEs were observed in the past 24 hours.

All considered, there is a Slight Chance of G1 on all days, rising to a peak Chance on Friday 30 December as a result of the relatively more reliable onset of the fast wind from CH59/+ (versus glancing CME arrivals).

Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux is expected to remain at Background levels throughout, with a daily Slight Chance of reaching S1

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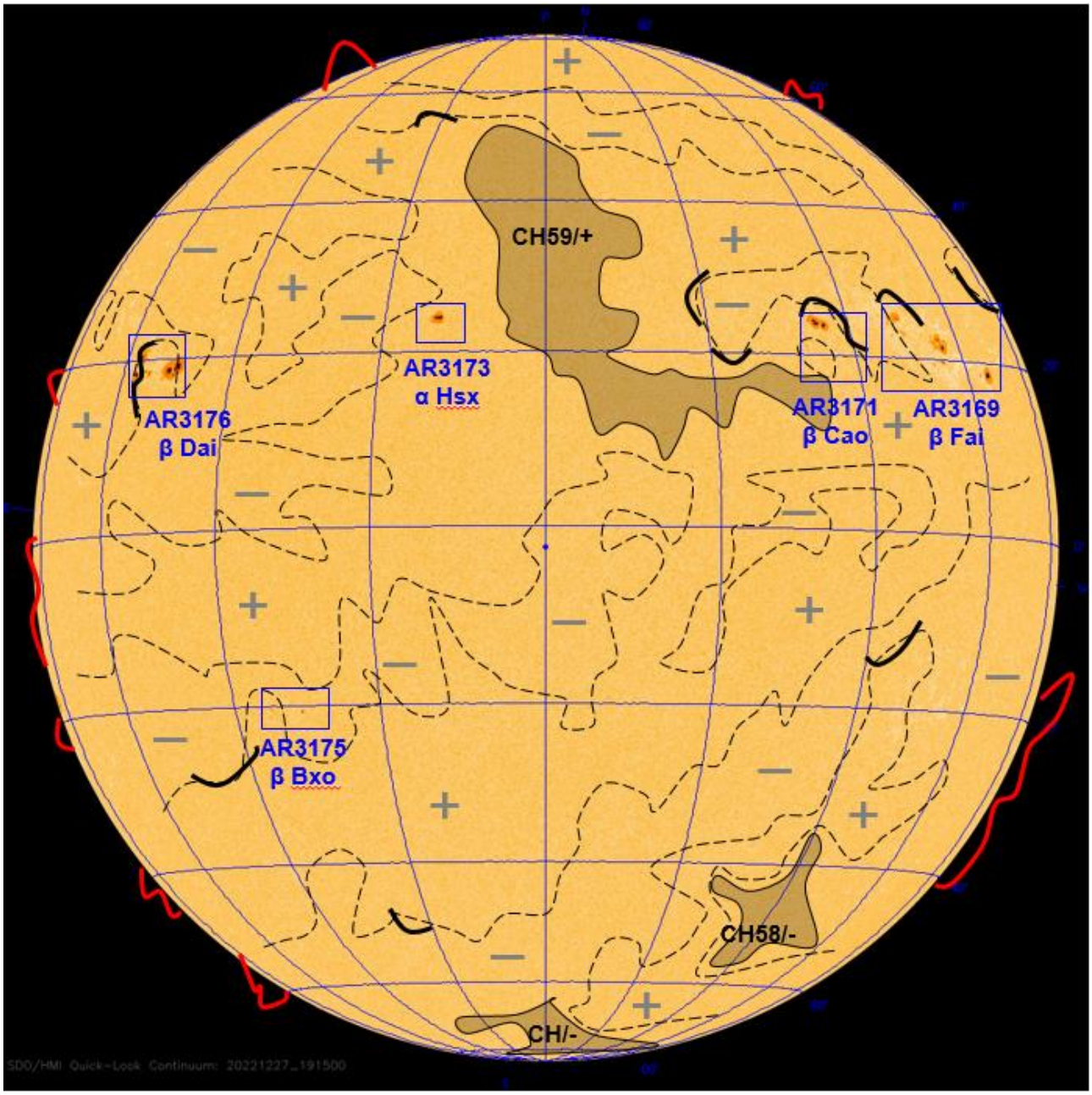
levels.

High energy electron flux (greater than 2MeV) forecast is low confidence given the lack of utility of persistence methods (due to CMEs and coronal hole changes). Whatever flux level is achieved in the next 24 hours should persist through midweek, perhaps reducing for a time should any CME effects materialise on 29 December and CH59 on 30 December, before recovering over the course of the UTC weekend - i.e. outside the forecast period - and to an uncertain degree given the lack of a suitable analogous coronal hole from last pass. Active fluence is Likely in the immediate term, falling to a Slight Chance by day four, Saturday 31 December.

Figure 1. Solar Analysis Valid 27/1915UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

The coming four-day forecast period features the fading of the current fast wind from CH57/+, with CH59/+ then due before the UTC weekend. Overlying this is a possible glance from a CME that left the Sun on 25 December, which should pass 1AU on 29 December, albeit with low confidence. A CME from 24/0800UTC was due on 27 December, and there is a small chance that there was some minor contribution to activity seen on that day. Should this not be the case, it has either already passed nearby to no effect, else should have its impacts lessen for being late in arriving (i.e. slower and less impactful). No new CMEs were observed in the past 24 hours.

The rationale for the geomagnetic forecast is therefore for waning effects of CH57/+ through midweek UTC, with the IMF now closing in and the Bz component becoming more erratic and smaller-scale after the CME arrival of 26 December. The 24/0800UTC CME may still be unaccounted for and there is therefore a suggested contributory factor to the Slight Chance of G1 on day one, Wednesday 28 December, albeit small.

Thursday 29 December should then see a possible slight uptick in activity should the 25 December CME feature, although this is a low confidence aspect of the forecast, with the CME assessed as mainly south and ahead of the Sun-Earth line.

Friday 30 December carries perhaps the peak risk of Minor Geomagnetic storm activity developing in the four-day forecast, with this arising from the onset of CH59/+. This is much-changed in stature versus last pass 27 days ago, hence lowering confidence as to its effects significantly. STEREO A is currently around a day upwind of Earth in sampling the solar wind at 1AU, and as such is not likely to provide any steer as to expected solar wind speeds until shortly before the event. MOSWOC Enlil has delayed its suggested onset time for the feature from 29 into 30 December, with a gradual rise through Elevated levels suggested, which is accepted given the hole's position on the disc. The chances of G1 should fall as the fast wind establishes over the UTC weekend, with much of the suggested Slight Chance of G1 on Saturday 31 December coming earlier in the UTC day.

Geo-Magnetic Storm	**Level**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Minor or Moderate	**G1 to G2**	Yes	10	20	40	20
Strong	**G3**	No	1	1	1	1
Severe	**G4**	No	1	1	1	1
Extreme	**G5**	No	1	1	1	1

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Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
24/1415	Partial	Potentially AR3169	NE quadrant	620km/s	Overdue or passed	Limited effects if still outstanding
25/1245	Partial	AR3169	NE quadrant	520km/s	29 December	Low confidence

Figure 2: Past three days of ACE L1 solar wind measurements, showing likely CME contribution best in IMF and Bz, with prolonged southward component resulting in G1 intervals. Also shown is ACE EPAM LEMS, which has been enhanced over the same period which is often diagnostic of CME passage, although there was no sharp discontinuity which means Earth may be sampling the shock or side lobe of the CME(s) only.

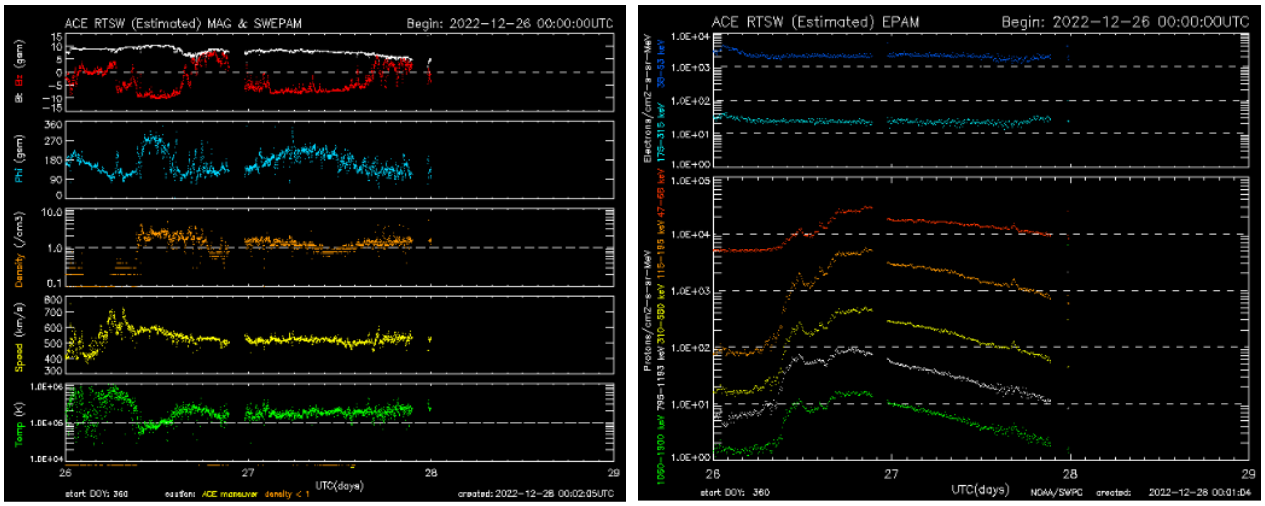
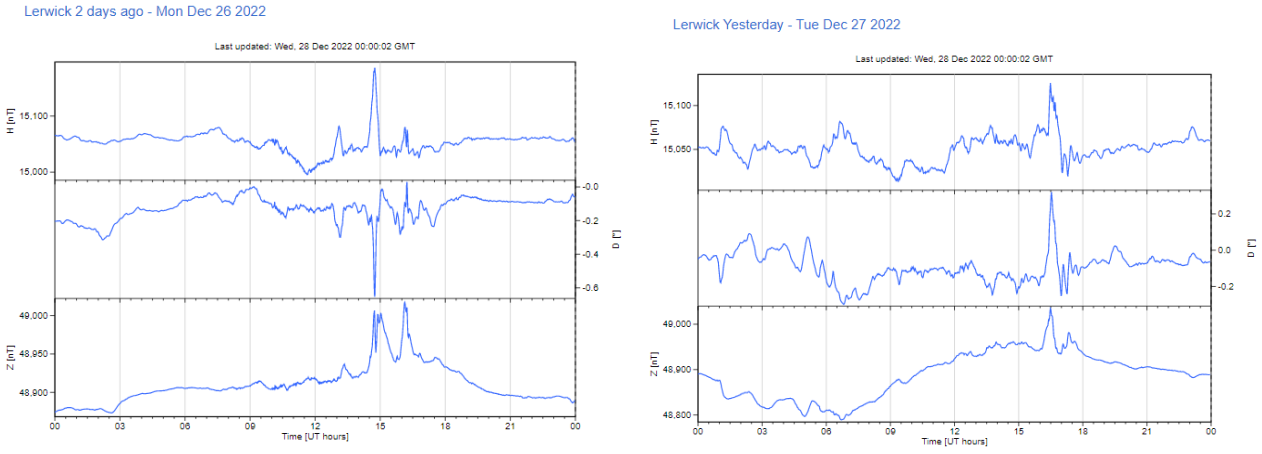


Figure 3: Past two days at Lerwick magnetometer (data courtesy of BGS). Note the two disturbances around 26/1500UTC and 27/1630UTC, perhaps signatures of CME arrivals at Earth, although preceding evidence at L1 was less strong, and they are perhaps the result of the end of lengthy preceding periods of negative Bz.


Lerwick 2 days ago - Mon Dec 26 2022
Last updated: Wed, 28 Dec 2022 00:00:02 GMT
Time [UT hours]
Lerwick Yesterday - Tue Dec 27 2022
Last updated: Wed, 28 Dec 2022 00:00:02 GMT
Time [UT hours]

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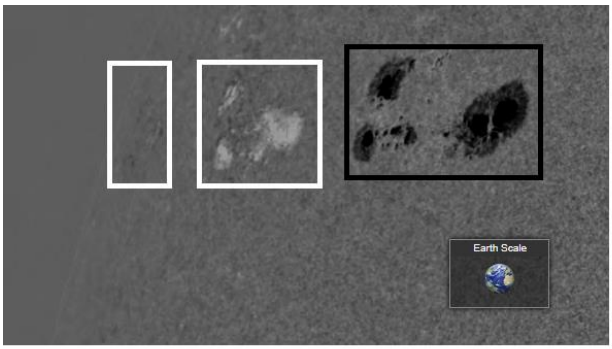
Radio Blackouts - X-Ray Flares:

Solar activity carries a daily Chance of M-class activity, with the main contributions from AR3169, AR3176 and perhaps now also an arriving southeastern limb spot group. The main source of activity in both the last 24 hours and in the coming four-day forecast (barring development elsewhere) is most likely to be in AR3176, which has shown areal growth, spreading and proliferation of its intermediate spots in the period.

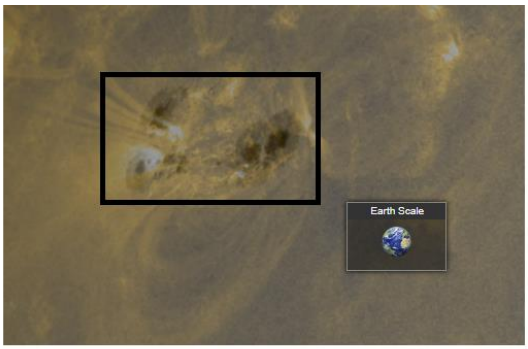
AR3169 is expected to depart the Earth-facing side through the course of day three, Friday 30 December, with its contribution to daily risks ceasing by the UTC weekend. Far-side soundings continue to suggest that there are sunspot regions lying narrowly over the eastern limb, however their presence is not yet confirmed and for now the X-ray flare risk is expected to fall with AR3169's departure.

X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	R1-R2 M Class	Yes	40	40	40	30
Very Active	R3 to R5 X Class	No	5	5	5	5

Figure 4: Helioviewer.org-generated composite imagery of (left) the growth from plage of AR3176 on the northeastern limb over the past 48 hours (white boxes are D-2 and D-1, current time boxed in black). Also shown (right) is an HMIIF and AIA171 composite, showing a proxy for magentic looping from the spot group.



HMIIF 28/000UTC; D-1 and D-2



28/000UTC HMIIF and AIA171

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Solar Radiation Storms - (High Energy Protons):

The high energy proton flux (greater than 10 MeV) is expected to remain generally at Background levels.

Forecast probabilities remain at a daily Slight Chance of S1 due to the ongoing possibility of larger flares from AR3169, and now also AR3176 and possibly a new arrival near the southeastern solar horizon. As yet there have been no slight enhancements observed from any of the M-class flares of 27 December, and it will be some time before the eastern hemisphere spots are realistically able to make themselves felt at Earth should they produce any protons enhancements.

Radiation Storms Probability (Exceedance)	**Level (cm^{-2} sr^{-1} s^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC) (%)**	**Day 2 (00-24 UTC) (%)**	**Day 3 (00-24 UTC) (%)**	**Day 4 (00-24 UTC) (%)**
Active	**≥ S1**	No	5	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

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High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) at GOES16 has been suppressed at GEO in the past 24 hours under the onslaught of occasional Minor Geomagnetic Storm activity, however it has shown a ready willingness to recover quickly, which implies that the Van Allen belts are perhaps comfortably populated in the wake of the fast wind of CH56/+ and now CH57 and the 24/0230UTC CME.

It is now possible that two of the three recent outstanding CMEs have now passed 1AU (being the 24/0230UTC and 24/0800UTC CMEs, due on 26 and 27 December respectively). Should this be the case, and with CH57/+ maturing, the prospects of further geomagnetic activity should lessen into 28 December to perhaps allow the belts to assume their more usual position and bolster counts recorded at GOES16. Any recovery will perhaps be short-lived, with a further fast wind enhancement and possible glancing incidence from the 25 December CME still to come. The weight of CMEs and changes in upcoming coronal hole geometries render persistence forecasting and REFM not useful, however MOSWOC Enlil's thoughts as to the expected arrival time of the upcoming CH59/+ have been pushed back to 30 December, perhaps because of the leading portion of the hole appearing to weaken.

Whatever flux level is achieved in the next 24 hours should persist through midweek, perhaps reducing for a time should any CME effects materialise on 29 December and CH59 on 30 December, before recovering over the course of the UTC weekend - i.e. outside the forecast period - and to an uncertain degree given the lack of a suitable analogous coronal hole from last pass.

GEO Electron Environment	**Level (cm^{-2} sr^{-1} day^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Active	**≥ 2 MeV ≥ $1x10^{8}$**	No	60	60	30	20
Very Active	**≥ 2 MeV ≥ $1x10^{9}$**	No	1	1	1	1

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